International Journal of Offshore and Polar Engineering
Vol. 8, No. 2, June 1998 (ISSN 1053-5381)

Survival Analysis of a Deep-Water Floating Offshore Platform About Its Critical Axis Including Coupling

Ravikiran S. Kota† and Jeffrey M. Falzarano*
School of Naval Architecture, University of New Orleans, Louisiana, USA

Alexander Vakakis
Department of Mechanical Engineering, University of Illinois, Urbana, Illinois, USA

ABSTRACT

Due to the movement of oil and gas exploration and production to deeper and deeper water depths, floating production systems are becoming ever more common. No longer are Column Stabilized Mobile Offshore Drilling Units (MODUs) being used only for site-temporary exploratory drilling; they are increasingly being considered for semipermanent production systems. As a result of this new purpose, analysis of their critical response when exposed to extreme winds and waves must be an ever more important aspect of their design. Unfortunately, vessel stability criteria are inadequate to study extremely large amplitude motions leading to capsizing. With respect to ships, much work has been done using dynamical systems approaches to study capsizing, and recently these same techniques have been extended and applied to study platform dynamics. This paper describes the global nonlinear dynamics of a typical MODU about its critical, approximately quartering axis. It is well-known that short and wide (i.e., small L/B ratio) twin-hull vessels such as MODUs have minimum righting moment about an approximately quartering axis. In a previous paper, Falzarano and Kota (1996) showed that this axis was also a critical rotational motion axis. In order to understand this problem, a global transient dynamical systems analysis was undertaken that compared the vessel's response at all heading angles. In the present work, an attempt is made to answer the question, What is the effect of the out-of-plane coupling? To answer this question advanced decoupling techniques known as nonlinear normal modes (Vakakis et al., 1996) are utilized. As an example, application of these techniques to the capsized MODU *Ocean Ranger* is also included.

BACKGROUND AND INTRODUCTION

This study is the result of a series of investigations that have analyzed the multiple degree of freedom nonlinear dynamics of marine vehicles using modern geometric methods over the last several years. These investigations have been possible only because of the developments outside the marine dynamics field in the applied mathematics and mechanics areas (Guckenheimer and Holmes, 1986). These previous investigations have considered steady state multiple degree of freedom ship motions at various headings (Falzarano et al., 1991 and Taz Ul Mulk and Falzarano, 1994), transient global nonlinear dynamics of single degree of freedom (Falzarano et al., 1992) and transient global nonlinear dynamics of ship roll motion coupled with sway and yaw (Falzarano and Zhang, 1993; Zhang and Falzarano, 1994). This work was subsequently extended to consider the nonlinear dynamics of floating offshore platforms (Falzarano et al., 1995). Most recently that work focused on the nonlinear dynamics of floating offshore platforms about their critical axis (Falzarano and Kota, 1996). In that work it was realized that the coupling of the out-of-plane righting arm although small at small angles continuously increased and became quite large at the in-plane angle of vanishing stability. It was realized at that time that the powerful methods of nonlinear normal modes (NNM) being developed outside the marine field by Vakakis et al. (1996) and Shaw and Pierre (1993) might provide valuable insight into this important problem. This paper summarizes the most significant results of this investigation; more complete details are described by Kota (1997).

PROBLEM FORMULATION

Description of Explicit Physical Model

The linearized 6 degree of freedom (DOF) equations of motion of a vessel, in the vessel coordinate system (Chakrabarti, 1985), can be written in a vector form as:

$$(\mathbf{M}+\mathbf{A}(\omega))\ddot{\underline{x}}+\mathbf{B}(\omega)\dot{\underline{x}}+\mathbf{C}\underline{x}+\mathbf{g}(\underline{x})=\underline{F}(t) \tag{1}$$

where the vector **x** represents the 6 degrees of motion, **M** is the 6×6 physical mass/inertia matrix, **A** and **B** are the hydrodynamic added mass and damping matrices, **C** is the linear part of the hydrostatic restoring force/moment, and the vector **g** is the nonlinear component of the restoring force/moment. Note that **A** and **B** are frequency dependent. The system is now modeled as a forced, nonlinear spring mass damper system that can be analyzed for response to any external input (initial conditions or forcing) using various techniques.

The focus of attention in this study is the dynamics of tilt about an arbitrary horizontal axis at an angle of orientation α with respect to the vessel's principal longitudinal axis. So, the roll and pitch equations are isolated from the general 6-DOF equation above, assuming that neither is coupled, to linear approximation, with any other DOF statically or inertially. Thus, we have the fol-

*ISOPE Member.
†currently at Aker Engineering, USA, Houston.

Received July 17, 1997: revised manuscript received by the editors November 10, 1997. The original version (prior to the final revised manuscript) was presented at the Seventh International Offshore and Polar Engineering Conference (ISOPE-97), Honolulu, USA, May 25-30, 1997.
KEY WORDS: Nonlinear dynamical systems, nonlinear normal modes, MODU, dynamical stability, floating platform motion.